

**Voucher:** USA. Alabama. Jackson County: Near Stevenson. Three miles south of Russell Cave National Monument and 2.5 mi northwest of U.S. Highway 72. Approximately 100 mature fronds and 50 individuals were growing on a wet flowstone wall of a vertical cave approximately 6 m below the entrance. The overall depth of the cave reaches nearly 60 m with the surface entrance located 925 ft (282 m) above sea level. GPS coordinates withheld. July 10, 2009. *Barger* #SP107 (AUA, JSU, TROY).

The authors thank Curtis Hansen and Jack Short along with the anonymous reviewers for their helpful comments in crafting this manuscript. Special thanks are extended to Dan Spaulding for his expert assistance with plant specimen identification and to Misako Nishino and John Kartesz for verification of county record data and the distribution map.—T. WAYNE BARGER, Natural Heritage Section, Alabama Department of Conservation, 64 N. Union Street, Montgomery, AL, 36130 U.S.A., ALAN CRESSLER, U.S. Geological Survey, 3039 Amwiler Road, Suite 130, Peachtree Business Center, Atlanta, GA, 30360 U.S.A., BRIAN D. HOLT, Natural Heritage Section, Alabama Department of Conservation, 64 N. Union Street, Montgomery, AL, 36130 U.S.A., and MAX MEDLEY, 519 W. Hawthorne A-13, Dalton, GA 30720 U.S.A.

**Review of Two Non-Native, Invasive Climbing Ferns (*Lygodium japonicum* and *L. microphyllum*), Sympatric Records and Additional Distribution Records from Florida.**—Two non-native species of climbing fern, *Lygodium japonicum* (Thunb.) Swartz and *L. microphyllum* (Cav.) R. Br. are currently present in Florida and are highly invasive in many natural areas of Florida (Gordon, *Ecol. Appl.* 8:975–989. 1998; Langeland *et al.*, *Identification and Biology of Nonnative Plants in Florida's Natural Areas* (2<sup>nd</sup> edition). IFAS Communication Services, University of Florida, Gainesville, FL. 2008). Both of these non-native ferns have become problematic to land managers in natural areas of Florida (Hutchinson *et al.*, *Old World Climbing Fern (*Lygodium microphyllum*) Management Plan for Florida*. South Florida Water Management District, West Palm Beach, FL. <http://www.fleppc.org>. 2006; FLEPPC, Florida Exotic Plant Pest Council's 2007 Invasive Plant Species List. Available on at: <http://www.fleppc.org/list/07list.htm>. 2007). Both ferns exhibit indeterminate growth growing horizontally and vertically, often forming complete cover over native vegetation. From 2005–2006, the total costs associated with control of upland invasive plants on Florida public lands (cities, counties, state and federal) was 9.4 million dollars (FLDEP, Florida Department of Environmental Protection, Bureau of Upland Plant Management (<http://www.dep.state.fl.us/lands/invaspec/2ndlevppls/Uplandsplntman.htm>). 2009). The Florida Fish and Wildlife Conservation Commission's Bureau of Invasive Plant Management currently ranks *Lygodium microphyllum* (Cav.) R. Br. along with hydrilla [*Hydrilla verticillata* (L.f.) Royal] as its priorities for research funding on control methods (Schmitz, *Nat. Areas J.* 27:251–253. 2007). In 2008,

*L. microphyllum* and *L. flexuosum* (L.) Sw. were recommended to be listed as Federal Noxious Weeds (USDA, *Weed Risk Assessment*. United States Department of Agriculture, Animal and Plant Health Inspection Service, Raleigh, N. C. 2008). While *L. flexuosum* is not currently present in the U.S.A., it has similar biological traits (i.e., long distance dispersal, ability to self-cross, fire tolerance) as both species of *Lygodium* now present in Florida (Lott *et al.*, *Am. J. Bot.* 90:1144–1152. 2003) and may be considered for ornamental use (USDA, 2008). The goals of this study were to examine the historical records of both climbing ferns currently present in Florida based on herbarium records, report on new sympatric records, and document new distribution records from north and south Florida.

The earliest known herbarium record of *L. microphyllum* in Florida is from Davenport in Polk County from January 6, 1958 (Florida Division of Plant Industry, Record # 0-3753). This report was for a specimen at Hollybrook Nursery indicating the fern was present in Polk County at this time. The specimen was turned in because of a fungus on the upper surface of the pinnae. This may indicate that the nursery was cultivating the fern if there was concern about the fungus or that they discovered a plant with a disease and wanted identification. The report suggests using Dithane Z-78 to control the fungus but no other details exist in the report. The second earliest herbarium record for *L. microphyllum* was reported February 11, 1958 (FLAS #P5100) from a nursery in Delray Beach, Florida on the southeast coast. There was no more information on this sample, but the plant was growing in a nursery indicating that it was being propagated or possibly arrived accidentally with other plants. These two reports indicate that *L. microphyllum* was present in 1958 at two different locations in Florida that are ca. 240 km apart. Old World climbing fern has spread across the landscape of Florida at a rapid rate since that time (reviewed in Pemberton and Ferriter, *Amer. Fern J.* 88:165–175. 1998). This species has been present in Florida for > 50 years and was first documented as naturalized in southeast Florida in 1965 (Beckner, *Amer. Fern J.* 58:93–94. 1968).

Based on herbarium records, *L. japonicum* has been present in Florida for at least 77 years. The earliest herbarium record of *L. japonicum* was from Polk County in 1931 (USF Accession #175179). It is widely scattered throughout Florida from the panhandle to extreme south Florida. The earliest herbarium records from the panhandle region of Florida are from 1948–1950. This species occurs throughout the southeast United States and has likely been introduced into Florida multiple times. Except for herbarium records, little information exists on *L. japonicum* in Florida. In northern Florida, it was reported that pine straw used for mulch contained *L. japonicum* spores and this has increased the dispersal and spread of the fern (Zeller and Leslie, *Wildland Weeds*. Summer: 6–9. 2004). It has been reported to form dense cover over native ground and shrub plants in both disturbed sites and natural areas of northern Florida (Langeland *et al.*, 2008).

Based on herbarium records, Polk and Highlands Counties in south-central Florida were the first known sites of both *L. japonicum* and *L. microphyllum* in

Florida. A 1935 record (FLAS P3270) exists for *L. japonicum* from the Florida Botanical Garden and Arboretum in Highlands County which later became part of Highlands State Park. In 1973, a park service biologist documented *L. microphyllum* as naturalized in Highland Hammock State Park (FLAS P7718). In a 2004 aerial surveys of Highlands and Polk Counties along the Lake Wales Region of south-central Florida, 213 locations with *Lygodium* spp. were documented with some infestations of *L. microphyllum* as large as 40–80 ha (Biehl, *Wildland Weeds* 7(3):4–5. 2004).

In a survey of Florida flora from 1927–1930, no reports of *Lygodium* spp. were documented (Moldenke, *Am. Midl. Nat.* 32:529–590. 1944). Since the 1930's, two non-native species of climbing fern, *L. japonicum* and *L. microphyllum*, have been documented from herbarium records in Florida (FLAS, University of Florida Herbarium (<http://www.flmnh.ufl.edu/herbarium/>). Gainesville, Florida. 2008; FSU, Florida State University Herbarium (<http://herbarium.bio.fsu.edu/index.php>). Tallahassee, Florida. 2008; FTG, Fairchild Tropical Gardens Herbarium (<http://www.virtualherbarium.org/default.html>). Miami, Florida. 2008; Wunderlin and Hansen, *Atlas of Florida Vascular Plants* (<http://www.plantatlas.usf.edu/>). Institute for Systematic Botany, University of South Florida, Tampa. 2008). Both species are listed as Category I invasive species by the Florida Exotic Pest Plant Council indicating they are disrupting natural communities by displacing native plant species and interrupting natural processes (FLEPPC, 2007). The Florida Department of Agriculture and Consumer Services prohibit the sale, propagation, or possession of both *L. japonicum* and *L. microphyllum* in Florida (FDACS, 2009). There is some documentation of these two non-native ferns occurring within the same habitat in close proximity. Prior to May 2000, both *L. japonicum* and *L. microphyllum* were documented in Little Manatee River State Park (Myers and Wunderlin, *Castanea* 68:56–74. 2003) indicating both species were established in west central Florida prior to 2000. Lockhart (Statewide *Lygodium* treatment site evaluation project. Florida Natural Areas Inventory, Tallahassee, FL. Available on at: [http://www.fnai.org/pdf/Lygodium\\_Report\\_2007.pdf](http://www.fnai.org/pdf/Lygodium_Report_2007.pdf). 2007) reported that both *L. japonicum* and *L. microphyllum* occurred at Avon Park Bombing Range and along the Kissimmee River Floodplain in Polk County. Both species were also observed growing together along a disturbed mesic / hydric ecotone in Sarasota and Palm Beach Counties in south Florida (Lockhart, 2007).

Nauman and Austin (*Amer. Fern J.* 68:65–66. 1978) reported *L. japonicum* and *L. microphyllum* were both well-established in different parts of Florida and suggested the two species would meet in central Florida. Historically, *L. japonicum* was most common north of Orlando with records as far south as Collier County, while *L. microphyllum* was most common south of the northern section of Lake Okeechobee with scattered populations into Polk County to the north (Pemberton and Ferriter, 1998). Herbarium records accessed on the internet from the University of Florida (FLAS, 2008), Florida State University (FSU, 2008), University of South Florida (Wunderlin and Hansen, 2008) and Fairchild Tropical Gardens (FTG, 2008) dating from 1930–2008 indicate that 70% ( $n = 190$ ) of documented occurrences of *L. japonicum* occur north of

TABLE 1. The five earliest known herbarium records for *L. japonicum* and *L. microphyllum* in Florida based on herbarium records.

Date	Accession #	County	Location
<i>L. japonicum</i>			
March, 1931	USF 175179	Polk	Winter Haven
March, 1932	FLAS P5939	Dade	Miami (vacant lot)
Unknown, 1934	FLAS P207	Alachua	Gainesville (cultivated)
January, 1935	FLAS P3270	Highlands	Sebring
January, 1935	FLAS P208	Collier	Naples (cultivated)
<i>L. microphyllum</i>			
January, 1958	DIP 0-3753	Polk	Davenport (nursery)
February, 1958	FLAS P5100	Palm Beach	Delray Beach (nursery)
August, 1960	FSU 4658	Martin	Jupiter
June, 1965	FLAS P6659	Martin	Hobe Sound
November, 1966	FLAS P6980	Martin	Jupiter

Orlando (N 28° 25'–WGS 84 Datum) while 98% (n = 91) of documented occurrences of *L. microphyllum* occur south of Orlando. Pemberton (Sida 20:1761–1761. 2003) reported a new population of *L. microphyllum* in east Orlando that increased the northern distribution by 70 km, an indication that the two species ranges have over-lapped further north than reported by Myers and Wunderlin (2003). A 2005 herbarium record from Volusia County, Florida indicated that *L. microphyllum* occurred ca. 90 km north of Orlando (USF #540261). This population of *L. microphyllum* was located ca. 3.5 km NE of Ormond Beach and ca. 13.0 km north of Daytona Beach.

Of the five earliest known herbarium records of *L. japonicum* in Florida, four of these records are from locations south of Orlando, two of which are from the southern end of the peninsula in Dade and Collier County (Table 1). However, *L. japonicum* has not spread across the landscape of south and central Florida to a similar extent as *L. microphyllum* and is more invasive in north Florida. Twenty-one percent of the herbarium records for *L. japonicum* that occur south of Orlando are from areas in Hillsborough, Pinellas, Manatee and Polk Counties indicating that *L. japonicum* has long been established in west-central Florida. Only 3.7% (n = 7) of documented records for *L. japonicum* occur in Dade and Collier Counties in the southern peninsula of Florida.

In 2005, the combined coverage of both species of *Lygodium* based on aerial surveys was estimated to be 74,122 ha in the central and south regions of Florida, with 48,898 ha in the southern region, most of which was likely *L. microphyllum* (Ferriter and Pernas, Wildland Weeds 9(2):7–9. 2006). During floral surveys of Water Conservation Areas 2 and 3 in the central Everglades, no reports of *Lygodium* spp. were documented in the late 1950's (Loveless, Ecology 40:1–9. 1959), but presently *L. microphyllum* is common on many tree islands in the central and northern Everglades. There are no known documented reports on the area coverage of *L. japonicum* and its area coverage in the central and northern Florida regions is unclear. Based on GIS analysis (Google Earth, <http://earth.google.com>. 2008) of *Lygodium* spp. in Florida from documented and undocu-

TABLE 2. City, county, GPS coordinates, year observed and habitat type of locations where *Lygodium japonicum* and *L. microphyllum* occurred concurrently in Florida.

City	County	GPS Coordinates <sup>1</sup>	Year Observed	Habitat Type
Lakeland	Lake	N 27° 55' 39.6", W 081° 57' 06.8"	2006	Maple swamp
Clermont	Lake	N 28° 23' 37.3", W 081° 45' 51.8"	2008	Cypress strand
Naples	Collier	N 26° 12' 47.7", W 081° 45' 52.2"	2008	Cypress strand
Balm	Hillsborough	N 27° 44' 26.4", W 082° 17' 43.6"	2006	Maple swamp

<sup>1</sup>- WGS 84 Datum

mented records, *L. microphyllum* currently ranges ca. 430 km in latitude (north to south) in peninsula Florida, while *L. japonicum* ranges ca. 550 km in longitude (east to west) along the panhandle and northern Florida, and ca. 570 km in latitude (north to south) along the peninsula. Based on herbarium records, this range expansion of both *Lygodium* spp. in Florida has occurred in < 80 years.

Expansion of *L. japonicum* is likely due to cultivation and propagule dispersal throughout the state from multiple introductions. The expansion of *L. microphyllum* is likely due to accidental introduction. The earliest known herbarium records of *L. japonicum* indicate it was first known from cultivation, while the earliest records of *L. microphyllum* indicate it was present in two nurseries. It has been reported that *L. microphyllum* was used as an ornamental (Gordon and Thomas, in D. Simberloff, D. C. Schmitz and T. C. Brown, *Strangers in Paradise*. Island Press, Washington, D. C. 1997). The introductions of these two climbing ferns, as well as many other non-native plants, indicates the need for better screening and evaluation of new plant introductions into Florida (Gordon, 1998; Gordon *et al.*, *Invas. Plant Sci. Mange.* 1:178–195. 2008).

*New sympatric records.*—From 2006–08, we observed four locations in which both *Lygodium* species occurred concurrently (Table 2). At three sites (Lakeland, Clermont, and Balm), there was a distinct habitat delineation between the two species. *Lygodium japonicum* was present at slightly higher elevations in a soil mixture of sand/humus, while *L. microphyllum* was present at lower elevations in humus soils. Elevation differences at sites where *L. japonicum* and *L. microphyllum* occurred together were < 1.0 m. Soils where *L. japonicum* was present were more xeric to mesic, while soils where *L. microphyllum* were present were more mesic to hydric. In addition, *L. japonicum* was observed in more open sites that were exposed to sunlight while *L. microphyllum* was observed in more shaded sites with > 50% canopy cover. At the Naples site, we observed both species growing together in a cypress strand, with *L. microphyllum* accounting for >99% cover. Canopy cover at the Naples site was >75% indicating that sunlight may be a factor in the distribution of these two ferns in Florida.

At Archbold Biological Station in Highlands County, one author (JTH) observed a small area (< 1 m<sup>2</sup>) of *L. japonicum* growing in association with multiple areas of *L. microphyllum* (> 50 m<sup>2</sup>). This sympatric population occurred at the edge of a bay swamp with a distinct delineation between the

two ferns. *Lygodium japonicum* occurred in a mesic site while *L. microphyllum* occurred in a hydric site on the edge of a bay swamp. The area coverage of both species was relatively small and neither was growing into the canopy, indicating they might have been recent arrivals.

In 2002, a herbarium record (USF #235222) was submitted for *L. japonicum* in St. Lucie County, where *L. microphyllum* is common along roadside canals (Morgan and Overholt, *Castanea* 70:59–62. 2005). There are herbarium records of *L. japonicum* from five counties in the southern one-third of peninsula Florida including St. Lucie, Martin, Palm Beach, Dade and Collier. Disconnected records for *L. japonicum* between southeast and southwest Florida may be due to low topography and humus soils of the Everglades region or a lack of herbarium submissions. However, it is clear that both *L. microphyllum* and *L. japonicum* are occurring together more frequently in habitats of the central Florida region.

In south Florida, it is unclear why *L. microphyllum* has spread so rapidly but *L. japonicum* still remains a minor floral component in all habitats of south Florida. One hypothesis for the differences in expansion is that *L. microphyllum* thrives in south Florida due to lower topography, humus soils and longer hydrological periods (Volin *et al.*, *Divers. Distrib.* 10:439–446. 2004), while *L. japonicum* exists in northern Florida due to higher topography, more mesic soils and shorter hydrological periods. Hydric conditions and humus soils may prevent the establishment of *L. japonicum* gametophytes and sporophytes, while drier conditions and sandy soils may prevent the establishment of *L. microphyllum* gametophytes and sporophytes. A second hypothesis may be temperature differences between north and south Florida. A third hypothesis is that *L. japonicum* is less competitive with native plants than *L. microphyllum*. All of these hypotheses are likely interrelated, but it appears that *L. japonicum* has failed to establish in high density in south Florida due to more hydric conditions and humus soils.

As more occurrences of these two invasive ferns occur at the same sites in peninsula Florida, it is possible that hybrids between *L. japonicum* and *L. microphyllum* could be produced. If they do hybridize, there is the potential for heterosis to occur (Hoshizaki and Moran, *Fern Growers Manual*. Timber Press, Portland, OR. 2001; Moran, *A Natural History of Ferns*. Timber Press, Portland, OR. 2004) and further invasion of Florida by the hybrid. While Knoblock *et al.* (*Taxon* 33:256–270. 1984) reported in a literature review of fern hybrids that there were no *Lygodium* hybrids and speciation in ferns by hybridization appears to be a rare event (Tryon, *Bot. Rev.* 52:117–156. 1986). Gomez (*Brenesia* 18:155–170. 1980) reported that hybrids are frequent within mixed populations of *Lygodium* species. For example, two species of *Lygodium* were reported to hybridize forming *Lygodium micans* x *venustum* in Trinidad that occur along different environmental gradients based on pinnae length (Fay, *Amer. Fern J.* 63:165. 1973; Jermy and Walker, *Bulletin of the British Museum, Botany* 13:251–276. 1985). In Trinidad, these two species are common with *L. micans* J.W. Sturm most commonly found in forest habitats and *L. venustum* Sw. is found in open sites. Gomez (1980) reports on

an additional hybrid of *Lygodium* spp. (*Lygodium* x *lancetillanum*) as a cross between *L. heterodoxum* Kunze and *L. ventustum*. Clearly, there seems to be potential for hybridization between *L. japonicum* and *L. microphyllum* which could affect future distributions of these species in Florida.

*Additional distribution records.*—During October 2008, we documented *L. japonicum* growing in the interior of a cypress strand in Naples, Florida (N 26° 12' 47.7", W 081° 45' 52.2"). Infestation of the fern was < 0.05 ha but at least five distinct populations were observed at the site. We observed *L. japonicum* growing at the base of bald cypress [*Taxodium distichum* (L.) Rich.] to heights of 2.5 m, where ground cover was dominated by *L. microphyllum* and the height of *L. microphyllum* was > than 15.0 m. Native plants found in association both species of *Lygodium* at Naples included bald cypress, groundsel tree (*Baccharis halimifolia* L.), wax myrtle [*Myrica cerifera* (L.) Small], myrsine [*Rapanea punctata* (Lam.) Lundell], slash pine (*Pinus elliotii* Engelm. var. *elliotii*), coco plum (*Chrysobalanus icaco* L.), swamp fern (*Blechnum serrulatum* Rich.), royal fern (*Osmunda regalis* L.), and muscadine (*Vitis rotundifolia* Michx.). Two non-native species were also found with the fern and included: creeping oxeye [*Wedelia trilobata* (L.) Pruski] and Brazilian pepper (*Schinus terebinthifolius* Raddi). The interior portion of the site was relatively undisturbed but was surrounded by development on all sides suggesting that hydrological and nutrient alterations have occurred. The site was dry at the time of the survey, but some soil moisture was present. It seems unlikely that *L. japonicum* was planted at this site, but invaded as spores from an unknown source. This species has been in Collier County since the 1930's.

In December 2008, we documented a new, previously unknown location of *L. microphyllum* in Lake County, Florida (N 28° 56' 40.9", W 081° 43' 03.5"). This population of *L. microphyllum* represents an ca. 40 km range increase to the north from the population reported by Pemberton (2003) along the central ridge of Florida, and is ca. 45 km south of a population of *L. microphyllum* documented along the east coast of Volusia County during February 2005 (Wunderlin and Hansen, 2008; Accession # 240261). The infestation was ca. 0.05 ha in size along floodplain habitat at Lake Holly. The fern occurred from the edge of the lake inward to about 25–30 m of the floodplain. The highest density and cover of the fern occurred ca. 5 m from the lakes edge, but scattered populations were found to the north, east and south. The fern was growing up to 4.5 m in height, equaling the height of the tallest native plants, and fertile pinnae were present. Some necrosis (ca. 10% total foliage) was observed due to recent freezes. Native plants associated with the fern at Lake Holly included coastalplain willow (*Salix caroliniana* Michx.), sawgrass (*Cladium jamaicense* Crantz), royal fern, swamp fern, wax myrtle and duck potato (*Sagittaria latifolia* Willd.). The non-native species, Peruvian primrosewillow [*Ludwigia peruviana* (L.) H. Hara], was also present. This new record along the central ridge of Florida may be an indication that *L. microphyllum* will become problematic in the lakes region of north central Florida.

In the extreme southeast part of peninsula Florida, undocumented records of *L. microphyllum* occur ca. 3.5 km west (N 25° 26' 01.1", W 080° 22' 00.7") of

Turkey Point Nuclear Power Plant in Florida City south of Miami. At this site the fern was well established, growing into Australian pine (*Casuarina equisetifolia* L.) to heights  $> 10$  m and along the edges of mangroves. This population occurs ca. 8 km southeast of Homestead, suggesting that *L. microphyllum* could invade tropical hammocks in Key Largo, which are located ca. 16 km to the south. According to the site manager in 2006 (Geoff West, Florida Power and Lights, pers. comm.), *L. microphyllum* occurs several km south of this site along Card Sound Road. As suggested by Goolsby (Nat. Areas J. 24:351–353. 2004), climates in Caribbean, Central and parts of South America are suitable for *L. microphyllum*, as well as habitats throughout the Florida Keys.

*Potential distribution in Florida.*—Herbarium records indicate that *L. japonicum* is well established throughout Florida, but is most invasive in the northern part of Florida. After  $>76$  years presence in Florida, it is unknown if *L. japonicum* will become as great a threat to wetland ecotones, forested swamps, and Everglades trees islands in southern Florida that *L. microphyllum* has become. However, the lag time before some non-native plants become invasive can be 70–100 years (Hobbs and Humphries, Conserv. Biol. 9:761–770. 1995). It is in the central Florida region from Ocala (N  $29^{\circ} 07'$ ) to Sebring (N  $27^{\circ} 28'$ ) where *L. japonicum* and *L. microphyllum* are likely to occur together out-competing native vegetation in natural areas. If the two ferns become dominant in the same natural habitat, it is unclear if control efforts (e.g., herbicides, biocontrol) will become more difficult. The Nature Conservancy's Central Florida Lygodium Strategy (CFLS) is designed to work with both private and public landowners in a 12 county region in central Florida region to stop the spread of *L. japonicum* into south Florida and *L. microphyllum* into north Florida (Higgins *et al.*, Nat. Areas J. 27:236–250. 2007; TNC, The Nature Conservancy - stopping the spread in central Florida (<http://www.nature.org/wherewework/northamerica/states/florida/science/art23406.html>). 2009). The goal of the CFLS is early detection and rapid response to treat *Lygodium* spp. within the 12 county region.

Goolsby (2004) suggested that defoliation of *L. microphyllum* and its inability to grow during periods of cold temperatures may limit its competitiveness with native plants, limiting its range to areas south of Orlando. We hypothesize that *L. microphyllum* will behave like *L. japonicum* during freezes and then re-sprout vigorously in northern Florida during the spring. The growing season is 270 days in northern Florida compared with 330 days along the southeast and southwest coasts of Florida (Henry *et al.*, *The Climate and Weather of Florida*. Pineapple Press, Inc., Sarasota, FL. 1994). It is likely that *L. microphyllum* has now invaded areas between Lake and Volusia Counties to the northeast, though no herbarium records currently exists. This area includes the St. Johns River basin where surface air temperatures are slightly warmer than the surrounding area. How successfully *L. microphyllum* invades and establishes north of Orlando is unknown, but all measures should be attempted to stop its spread into north-central Florida. Stopping the spread of *L. microphyllum* into south Florida rocklands including the Florida Keys is



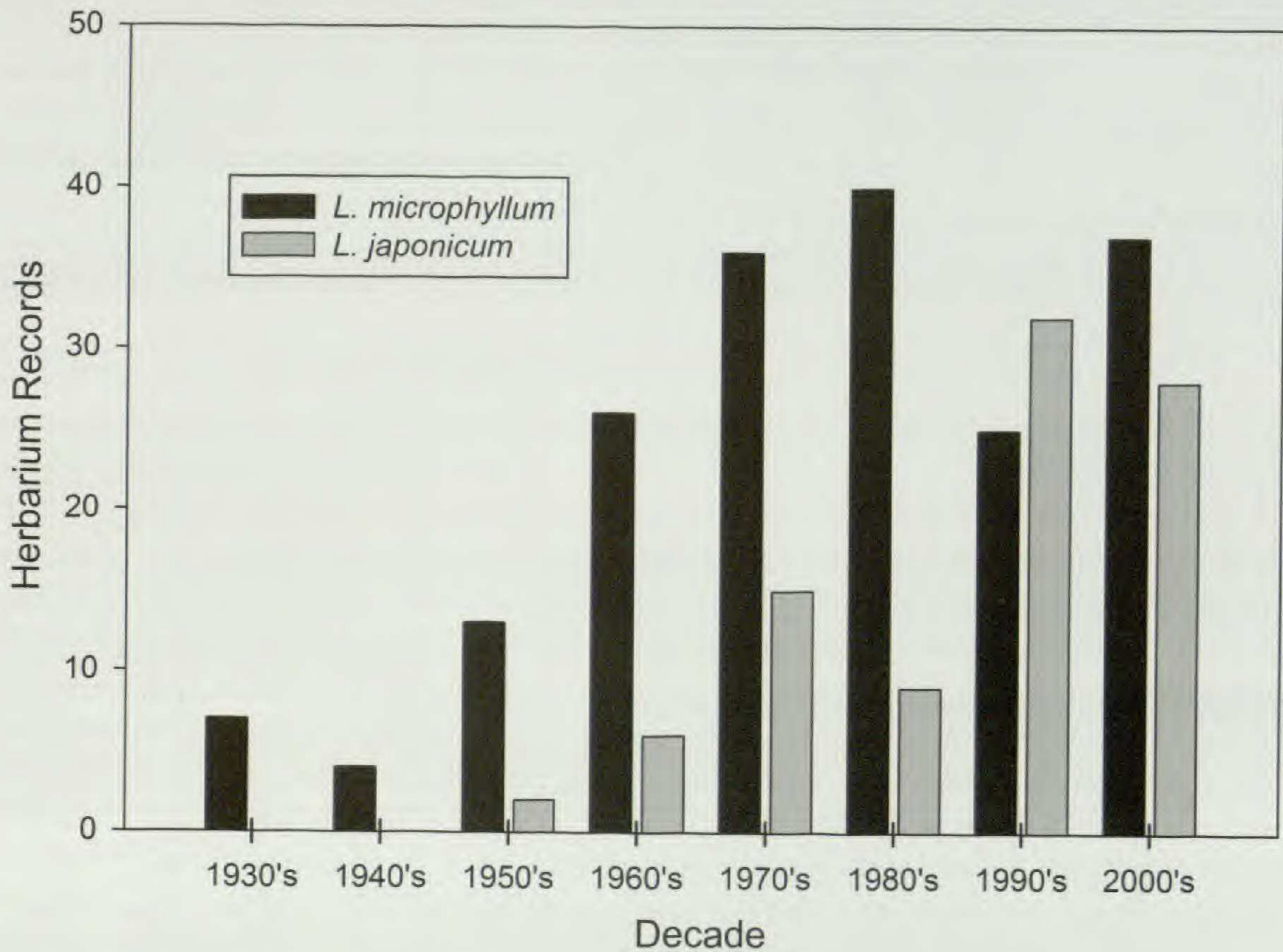


FIG. 1. Number of herbarium records per decade from UF (FLAS), FSU, USF (Wunderlin and Hansen 2008) and Fairchild Tropical Gardens (FTG) for *L. japonicum* and *L. microphyllum* per decade.

equally important because this habitat has numerous endemic plants. The lack of freshwater and humus soils may limit the spread of *L. microphyllum* in the Florida Keys.

It is clear that *L. microphyllum* has spread into USDA Cold Hardiness Zone 9A in Florida where the average minimum temperature can range between  $-6$  to  $-3$  °C. North Florida receives 4–9 days in December and 5–11 days in January in which the temperatures drops below 0 °C, while south Florida only receives 0–1 days in both December and January in which the temperatures drops below 0 °C (Henry *et al.*, 1994). Potentially, *L. microphyllum* could spread along the southeast coast of Florida northward to the Jacksonville/Georgia border, north along the central ridge to Ocala, and along the west coast of Florida to the northern edge of Citrus County or southern Levy County. This is the potential northern range of *L. microphyllum* suggested by Pemberton (2003) and Goolsby (2004). In lab experiments, we observed young sporophytes of *L. microphyllum* resprout after three hours at  $-2.2$  °C and spore germination following 12 hours at  $-2.2$  °C (Hutchinson and Langeland, unpubl. data).

**Conclusions.**—Based on herbarium records (FLAS, FSU, USF and FTG), there were increased reports of *L. japonicum* during the 1960's and *L. microphyllum* in the 1990's (Fig. 1). Considering that *L. japonicum* was first documented in Florida ca. 1930, it appears that within 30 years of being

documented it had began to spread across the state, possibly from multiple introductions and increased propagule pressure. Yet, *L. japonicum* has failed at this point in time to establish and invade natural areas of south Florida. We observed a similar invasive pattern based on herbarium records of *L. microphyllum*, in which increased herbarium records were documented ca. 30 years after it was first reported in Florida. However, it is unknown if *L. microphyllum* was introduced into more than two sites in Florida. It was reported that *L. microphyllum* was sold at Royal Palm Nursery in Manatee County from 1888–1930, but evidence from a photo in the nurseries catalogue and a description of its hardiness indicates it was *L. japonicum* (Pemberton and Ferriter, 1998).

Based on our observations and those of Lockhart (2007), coverage of *L. microphyllum* dominates *L. japonicum* in sites where these species are sympatric. Based on limited observations in Florida, these two species can occur in close proximity, but are separated by distinct ecotones based on slight changes (< 1.0 m) in elevation. There is evidence that introduced species and habitat disturbance within a new range may create ideal situations for hybridization and possibly heterosis in ferns (Walker, *Evolution* 12:82–92. 1958; Fay, 1973; Gomez, 1980; Kentner and Mesler, *Am. J. Bot.* 87:1168–1174. 2000). Habitat disturbances are numerous in Florida and two invasive climbing ferns are now present in close proximity. Both *L. japonicum* and *L. microphyllum* foliage exhibit high necrosis (i.e., up to 100%) from hard frosts, but re-sprouting occurs from rhizomes below the soil, indicating these species can tolerate temperatures  $\leq 0^{\circ}\text{C}$ . *Lygodium microphyllum* may exhibit the same tolerances as *L. japonicum* with regard to temperature, while invading further into north Florida. It remains unclear if *L. japonicum* will invade natural areas of southern Florida, but with multiple introductions throughout the state and the potential for long distance dispersal by spores, it is possible that this species may increase at an exponential rate.—JEFFREY T. HUTCHINSON and KENNETH A. LANGELAND, University of Florida, Agronomy Department, Center for Aquatic and Invasive Plants, 7922 NW 71<sup>st</sup> Street, Gainesville, Florida, U.S.A.

**Carbon Isotope ( $\delta^{13}\text{C}$ ) Signatures of Rheophytic *Dipteris lobbiana*.**—As with most plant groups, ferns show their highest diversity in the tropics (Mutke and Barthlott, *Biol. Skr.* 55:521–537. 2005). *Dipteris lobbiana* (Hook. f.) Moore is a fern species found commonly growing in riparian habitats throughout the tropical island of Borneo where it is often strongly attached to rocks along and within streams (Fig. 1). It belongs to the family Dipteridaceae which has two genera and nine species found only in the Palaeotropics (Kramer, in K. U. Kramer & P. S. Green eds. *The Families and Genera of Vascular Plants Vol. 1. Pteridophytes and Gymnosperms*: 99–101. Springer-Verlag, Berlin, Germany. 1990).